REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
15-11-2013	Final Report	6-May-2009 - 15-Aug-2013

4. TITLE AND SUBTITLE

Multimodal Signal Processing for Personnel Detection and Activity Classification for Indoor Surveillance

5a. CONTRACT NUMBER

W911NF-09-1-0244

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

611102

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)

U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)

ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

56021-MA.27

12. DISTRIBUTION AVAILIBILITY STATEMENT

Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

This goal of this project was to develop novel schemes for the fusion of heterogeneous information. The target application was the detection and classification of personnel activity in both indoor and outdoor environments under dependent observations. We have identified features and designed a classifier that achieves up to 95% classification accuracy on classifying the occupancy with indoor footstep data. MDL-based copula selection strategies are investigated and a detector based on vines is designed that extends previous bivariate copula-based

15. SUBJECT TERMS

Sensor fusion, heterogeneous information fusion, personnel detection, copula theory, multivariate-copulas, PCRLB, feature selection, classification, distributed estimation, data falsification attack, Byzantines

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Pramod Varshney
UU	UU	UU	UU		19b. TELEPHONE NUMBER
					315-443-4013

Report Title

Multimodal Signal Processing for Personnel Detection and Activity Classification for Indoor Surveillance

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This goal of this project was to develop novel schemes for the fusion of heterogeneous information. The target application was the detection and classification of personnel activity in both indoor and outdoor environments under dependent observations. We have identified features and designed a classifier that achieves up to 95% classification accuracy on classifying the occupancy with indoor footstep data. MDL-based copula selection strategies are investigated and a detector based on vines is designed that extends previous bivariate copula-based detectors to a multi-sensor application. Our copula-based detectors yield more than 40% improvement over the conventional data fusion methodologies. We extend our solution to quantized sensor information and demonstrate that injecting controlled noise can dramatically reduce computational complexity with insignificant performance loss. We propose and derive the Conditional Posterior Cramér-Rao Lower Bound (CPCRLB) for online tracking. We demonstrate that the PCRLB-based iterative approach converges quickly with significantly reduced computational cost as compared to a one-shot approach. Detector design in the presence of security threats, such as data falsification attacks to sensor networks, are also addressed. Error-control codes and decoding algorithms are used to reliably classify data in a network containing human agents.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
08/29/2011	1.00	Satish G. Iyengar, Pramod K. Varshney, Thyagaraju Damarla. A Parametric Copula-Based Framework for Hypothesis Testing Using Heterogeneous Data, IEEE Transactions on Signal Processing, (05 2011): 2308. doi: 10.1109/TSP.2011.2105483
08/29/2011	2.00	Ruixin Niu, Pramod K. Varshney, Long Zuo. Conditional Posterior Cramér-Rao Lower Bounds for Nonlinear Sequential Bayesian Estimation, IEEE Transactions on Signal Processing, (01 2011): 1. doi: 10.1109/TSP.2010.2080268
08/29/2012	13.00	Satish G. Iyengar, Ruixin Niu, Pramod K. Varshney. Fusing Dependent Decisions for Hypothesis Testing With Heterogeneous Sensors, IEEE Transactions on Signal Processing, (09 2012): 4888. doi: 10.1109/TSP.2012.2202113
08/31/2011	9.00	Ashok Sundaresan, Pramod K. Varshney. Location Estimation of a Random Signal Source Based on Correlated Sensor Observations, IEEE Transactions on Signal Processing, (02 2011): 787. doi: 10.1109/TSP.2010.2084084
08/31/2011	10.00	Priyadip Ray, Pramod K. Varshney. Radar Target Detection Framework Based on False Discovery Rate, IEEE Trans. Aerosp. and Electronic Systems, (04 2011): 1277. doi: 10.1109/TAES.2011.5751258
08/31/2011	11.00	M Keskinoz, Engin Masazade, Ruixin Niu, P K Varshney. Energy Aware Iterative Source Localization for Wireless Sensor Networks, IEEE Transactions on Signal Processing, (09 2010): 4824. doi: 10.1109/TSP.2010.2051433

TOTAL: **6**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

<u>Received</u> <u>Paper</u>

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

<u>Received</u> <u>Paper</u>

08/29/2011 7.00 Arun Subramanian, Satish G Iyengar, Pramod K Varshney, Thyagaraju Damarla. A Copula-based Framework for Heterogeneous Information Fusion,
Second Annual Human and Light Vehicle Detection Workshop. 03-MAY-11, . : ,

TOTAL: **1**

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received		Paper
08/29/2011	5.00	Arun Subramanian, Ashok Sundaresan, Pramod K Varshney. Fusion for the detection of dependent signals using multivariate copulas, 14th International Conference on Information Fusion (FUSION), 2011. 05-JUL-11, . : ,
08/29/2012	14.00	Thyagaraju Damarla, Hao He, Arun Subramanian, Pramod K. Varshney. Fusing Heterogeneous Data for Detection Under Non-stationary Dependence, 15th International Conference on Information Fusion. 11-JUL-12, . : ,
11/06/2013	19.00	Bhavya Kailkhura, Swastik Brahma, Yunghsiang S. Han, Pramod K. Varshney. Optimal distributed detection in the presence of Byzantines, ICASSP 2013 - 2013 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). 26-MAY-13, Vancouver, BC, Canada. : ,
11/06/2013	18.00	Bhavya Kailkhura, Yunghsiang S. Han, Swastik Brahma, Pramod K. Varshney. On covert data falsification attacks on distributed detection systems, 2013 13th International Symposium on Communications and Information Technologies (ISCIT). 04-SEP-13, Surat Thani, Thailand. : ,
11/06/2013	20.00	Aditya Vempaty, Lav R. Varshney, Pramod K. Varshney. Reliable classification by unreliable crowds, ICASSP 2013 - 2013 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). 26-MAY-13, Vancouver, BC, Canada. : ,
11/06/2013	21.00	Aditya Vempaty, Yunghsiang S. Han, Pramod K. Varshney. Byzantine tolerant target localization in wireless sensor networks over non-ideal channels, 2013 13th International Symposium on Communications and Information Technologies (ISCIT). 04-SEP-13, Surat Thani, Thailand. : ,
11/06/2013	22.00	Hao He, Arun Subramanian, Xiaojing Shen, Pramod K. Varshney. A coalitional game for distributed estimation in wireless sensor networks, ICASSP 2013 - 2013 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). 26-MAY-13, Vancouver, BC, Canada. : ,

TOTAL: **7**

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received		Paper
09/05/2012	16.00	E. Masazade, P. K. Varshney, P. Ray, R. Niu. Distributed Detection in Wireless Sensor Networks, Handbook of Multisensor Data Fusion (12 2011)
09/06/2012	17.00	Pramod K. Varshney, Engin Masazade. Distributed Signal Detection, Elsevier E-Reference Signal Processing (05 2012)
TOTAL:		**2**

Number of Manuscripts:

Books

Received		Paper
08/29/2011	4.00	Pramod K Varshney, Thyagaraju Damarla, Satish G Iyengar. "Biometric authentication: a copula based approach" in Multibiometrics for Human Identification, New York, NY: Cambridge University Press, (06 2011)
09/05/2012	15.00	Long Zuo, Engin Ma?azade, Ruixin Niu, Pramod K. Varshney . "Conditional Posterior Cramer-Rao Lower Bound and its Applications in Adaptive Sensor Management" in Distributed Video Sensor Networks, London: Springer, (02 2011)
TOTAL:		**2**

Patents Submitted

Patents Awarded

Awards

Pramod K. Varshney was awarded the IEEE Judith A. Resnick Award in 2012.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Hao He	0.50	
Arun Subramanian	0.50	
FTE Equivalent:	**1.00**	
Total Number:	**2**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Pramod Varshney	0.10	
FTE Equivalent:	**0.10**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Please refer to the attachment.

Technology Transfer

Statement of the problem studied

To develop algorithms for distributed inference applications, such as detection, classification, and target localization, for data obtained from heterogeneous sensors (including human sources).

Summary of most important results

1. Data collection.

A data collection effort at Syracuse University has resulted in a signal database generated from human indoor activity monitored by heterogeneous (multi-modal) sensors. The sensor suite comprised seismic, acoustic and video modalities. The experiments conducted under this setup were focused on a controlled scenario to enable a better understanding of signal behavior under excitation from human source. The environment was representative of a typical office setup consisting of a hallway with adjoining rooms. These experiments have led to the design of personnel detection and occupancy classification strategies (See items 3 and 4). Along with this indoor data, we have also collaborated with the US Army Research Laboratory and have applied our algorithms to an outdoor data-set collected at the US southwest border.

2. Copula-based dependence characterization for inference with heterogeneous sensor data.

We have used copulas to characterize the dependence and joint distribution between different sensor observations. Copula theory allows us to specify a multivariate distribution by coupling disparate marginal distributions of individual sensor observations. In other words, an explicit functional relationship between the joint distribution and its corresponding marginal distributions is specified and is called the copula function. Several copulas are defined in the literature, and therefore, copula selection is an important part of the inference problem.

2.1 Contributions to theory

We developed relevant theory for copula-based inference.

(a) Copula-based detection/classification. We have addressed the copula selection issue for the detection problem using approaches based on area under the ROC and average loss of detection power [1, 2]. Asymptotic performance loss due to misspecification of the copula function in terms of error exponents is also quantified.

(b) Multivariate dependence. We have developed a detection scheme that considers multi-sensor dependence using a copula-based approach [3]. Past applications using the copula-based approach have mostly been limited to the bivariate (2 sensor) case. Our detector is asymptotically optimal in the Neyman-Pearson sense. A multivariate copula is constructed based on the theory of vines. A novel tail dependence based node ordering scheme is proposed. Copula selection is performed using various minimum description length (MDL) criteria. We have shown that accounting for multivariate dependence, along with the node ordering, leads to significant improvement over a bivariate approach.

(c) *Distributed detection and detection with dependent quantized data.* Sensor observations (or features extracted thereof) are most often quantized before their transmission to the fusion center for bandwidth and power conservation [1, 4]. A detection scheme is proposed for this problem assuming uniform scalar quantizers at each sensor. The designed rule is applicable for both binary and multibit local sensor decisions. An alternative suboptimal but computationally efficient fusion rule is also designed which involves injecting a deliberate disturbance to the local sensor decisions before fusion. The rule is based on Widrow's statistical theory of quantization. Addition of controlled noise helps to linearize the highly nonlinear quantization process thus resulting in computational savings. It is shown that although the introduction of external noise does cause a reduction in the received signal to noise ratio, the proposed approach can be highly accurate when the input signals have bandlimited characteristic functions, and the number of quantization levels is large. The proposed fusion rule reduces computational complexity from $O(2^N)$ to $O(N \log N)$.

(d) *Nonstationary dependence.* The problem of detection for dependent, non-stationary signals where the non-stationarity is encoded in the dependence structure is considered in [5]. A sample-wise copula selection scheme for a simple hypothesis test is proposed. We prove that the proposed scheme performs better than previously used single copula selection schemes.

2.2 Applications

The developed theories were applied to the following applications.

(a) *Footstep detection for indoor seismic/acoustic data.* A generalized likelihood ratio test (GLRT) based approach is applied to the seismic-acoustic fusion problem for footstep detection [2]. Spectral features (STFT) are calculated locally, at the sensor level. The fusion center uses a canonical correlation analysis (CCA) to transform the spectral signatures so that the features are maximally correlated. Copulas are used to characterize the nonlinear dependence and a GLRT decides the presence or absence of a footstep signal. The maximization of the likelihood function is done over both the parameter space of a given copula, as well as the family of copulas considered in the library. The copula selection is thus contained within the GLRT and is performed online. The generalized Gaussian distribution is used to model marginal statistics. The detector is tested against normal walk, brisk walk and running activities. For a 0.05 false-alarm probability, the copula based approach provides on an average 7% improvement in detection rate over product fusion under independence assumption. The copula-based approach is extended to a semi-parametric framework [6], wherein we investigate the effect of ignoring the marginal distribution on detector performance. The marginal distribution in many cases is difficult to model due to non-stationarity and temporal dependence. Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are heuristic measures of information that are adopted for copula selection. Detection performance is evaluated for the seismic footstep data. The receiver operating characteristics show that the copula selected using either AIC or BIC is the best performing copula, i.e., the detector based on that copula has the highest probability of detection for a fixed probability of false alarm. The copula selected using AIC/BIC is seen to give best detection performance.

(b) *Footstep detection for outdoor seismic/acoustic data.* A copula-based detector using the Neyman-Pearson framework is designed. This detector implements the sample-wise copula selection scheme. We demonstrate the utility of our copula-based approach on simulated data, and also for outdoor sensor data collected by the Army Research Laboratory at the US southwest border. Our results show a 40% improvement in the probability of detection over conventional fusion schemes [5].

(c) *Classification of heavy-tailed signals.* The copula-based multiinformation estimate is applied to a classification problem with heavy-tailed signals. Our copula-based features give a classification accuracy of up to 85% on test data [7]. The test data were EEG signals that were used to classify early onset of Alzheimer Disease.

(d) *Biometric classification.* The copula framework yields superior results when applied to a multi-biometric person recognition dataset (NISTBSSR 1) [8]. We use a training-testing paradigm for this task. The copula parameters are learned during training, and thus during testing we do not need to estimate the parameters. Copula selection is done offline and two methods are proposed based on (a) area under the ROC, and (b) area under the probability of detection curve. The latter provides reduced computational complexity and provides a systematic KL-divergence based approach for copula selection.

3. Feature identification and neural network classification for occupancy classification

We have proposed a feature selection scheme for occupancy classification [9]. The classifier aims to determine whether there is exactly one occupant or more than one occupant. Data are obtained from six seismic sensors (geophones) that are deployed in a typical building hallway. After exploring multiple alternatives, we identified four features as being capable of assisting classification with a high degree of reliability. The four proposed features exploit amplitude and temporal characteristics of the seismic time series. A neural network classifier achieves performance ranging from 77% to 95% on the test data, depending on the type of construction of the location in the building being monitored.

4. Estimation

Several estimation problems under various scenarios were investigated.

(a) *Conditional Posterior Cramér-Rao Lower Bounds for nonlinear sequential Bayesian estimation [10].* We have proposed and developed a new measure of online tracking performance: the Conditional Posterior Cramér-Rao lower bound (CPCRLB). Posterior Cramér-Rao lower bounds (PCRLBs) for sequential Bayesian estimators provide a performance bound for a general nonlinear filtering problem. However, the unconditional PCRLB is an off-line bound whose corresponding Fisher information matrix (FIM) is obtained by taking the expectation with respect to all the random variables, namely the measurements and the system states. As a result, the unconditional PCRLB is not well suited for adaptive resource management for dynamic systems. The new concept of conditional PCRLB is dependent on the actual observation data up to the current time, and is implicitly dependent on the underlying system state. Therefore, it is adaptive to the particular realization of the underlying system state, and provides a more accurate and effective online indication of the estimation performance than the unconditional PCRLB. Both the exact conditional PCRLB and its recursive evaluation approach including an approximation are derived. A general sequential Monte Carlo solution is proposed to compute the conditional PCRLB recursively for nonlinear non-Gaussian sequential Bayesian estimation problems. Simulation results show quick convergence for the recursive computation of the CPCRLB.

(b) *Source localization in wireless sensor networks.* A well-known method for static source localization is uses the energy readings of all sensors in the network. However, transmitting all sensor data to the fusion center may introduce communication and energy overhead. We consider the source localization problem in the presence of networked sensors. We propose an energy efficient iterative localization scheme, where the algorithm starts with a coarse location estimate obtained from a set of anchor sensors [11]. A subset of the non-anchor sensors is selected and corresponding sensors are activated in each iteration. The observations from these sensors are used to minimize the Posterior Cramér-Rao Lower Bound (PCRLB). Using the available information received at previous iterations as side information, the quantized data of each activated sensor is further compressed to conserve energy using distributed data compression techniques prior to transmission to the fusion center. Simulation results show that the proposed iterative method achieves the same estimation performance as when all the sensors transmit their quantized data to the fusion center within a few iterations, while at the same time significantly reducing the communication requirements resulting in energy savings. For selecting sensors at each iteration, we have developed and compared two sensor selection metrics based on mutual information (MI) and PCRLB. We show that our PCRLB-based method performs as well as the MI based approach, but does so with a significantly reduced computational burden. As a function of the number of selected sensors, the complexity to compute the MI grows exponentially, while the complexity of PCRLB computation increases only linearly. We extend our work considering channel fading between sensors and the fusion center where we consider complete and partial channel knowledge at the fusion center [12]. Simulation results show that partial channel knowledge at the fusion center achieves the estimation performance very close to that of having the complete channel knowledge.

(c) *Distributed estimation under non-identical noise distribution.* We consider the problem of distributed estimation with heterogeneity in measurement error [13]. The observation noise of each sensor is independent but not identically distributed and each sensor transmits different amount of data to the fusion center depending on the quality of the sensor observation. We show that the complexity to compute average PCRLB (A-PCRLB) is high. We have, therefore, developed the inverse of the average Fisher information as a lower bound on the A-PCRLB. We assume a constraint on the total bandwidth. Each sensor, sending data at a specific quantization rate, uses a certain transmission probability to send its data to the fusion center. Under stringent availability of bandwidth, simulation results show that the proposed probabilistic transmission scheme outperforms the scheme in terms of MSE where the total bandwidth is equally distributed among sensors.

(d) *Coalitional game for distributed estimation.* In [14], we consider a collaborative estimation problem using dependent observations in a wireless sensor network, where each sensor aims to maximize its estimation performance in terms of Fisher information (FI) by forming coalitions with other sensors and collaborating within a coalition. The energy consumed by the sensors increases with the size of the coalition. The distributed estimation problem is formulated by taking into account this trade-off between minimized energy consumption and maximized Fisher information, and is, therefore, cast in a game theoretic framework. We prove that grand coalition will not form. We investigate the formation of non-overlapping coalitions such that each sensor's performance is maximized under a specific energy constraint. We decouple marginal and dependent components of FI obtained from the joint distribution by using copula theory. We introduce the novel concepts of diversity gain and redundancy loss and demonstrate how a copula-based formulation allows us to characterize these concepts. A merge-and-split algorithm is used for finding an optimal partition.

5. Distributed inference in the presence of Byzantine (unreliable) sensor nodes

Byzantines are nodes are those sensor nodes that alter their observations, and thus provide false information to the fusion center. In distributed detection systems, where nodes make one bit decisions regarding the presence of a phenomenon and collaboratively make a global decision at the fusion center (FC), Byzantines essentially flip their decisions before transmission to the FC. The performance of such systems strongly depends on the reliability of the nodes in the network. The robustness of distributed detection systems against attacks is of utmost importance for the functioning of distributed detection systems.

The problem of optimal distributed detection with independent identical sensors in the presence of Byzantine attacks is considered in [15]. By considering an attacker to be strategic in nature, we address the issue of designing the optimal fusion rule and the local sensor thresholds that minimize the probability of error at the fusion center (FC). We have addressed the problem of finding the optimal fusion rule under the constraint of fixed local sensor thresholds and fixed Byzantine strategy. We have also considered the problem of joint optimization of the fusion rule and local sensor thresholds for a fixed Byzantine strategy. These results are extended to the scenario where both the FC and the Byzantine attacker act in a strategic manner to optimize their own utilities. We model the strategic behavior of the FC and the attacker using game theory and show the existence of Nash Equilibrium. We observed that the joint optimization solution is independent of the Byzantine parameters.

The problem of covert attacks by Byzantine nodes is addressed in [16]. We introduce the problem of intelligent data falsification attacks on distributed detection systems. We propose a scheme to detect data falsification attacks and analytically characterize its performance. We determine the optimal attacking strategy from the point of view of a smart adversary to disguise itself from the proposed detection scheme while accomplishing its attack.

In [17], an energy efficient localization scheme is proposed by modeling it as an iterative classification problem. We designed coding based iterative approaches for target localization. The FC iteratively solves an M-ary hypothesis test and decides the Region of Interest (ROI) for the next iteration. We also consider the presence of Byzantine (malicious) sensors in the network. We investigate the localization scheme over non-ideal channels and propose the use of soft-decision decoding to compensate for the loss due to the presence of fading channels between the local sensors and the FC. We show that the proposed soft-decision decoding scheme outperforms previously proposed hard-decision decoding schemes, both, in terms of target detection probability as well as the mean square error of location estimate. Using the soft-decoding scheme, we demonstrate in improvement of about 20% in detection probability and about a 50% reduction in the MSE for localization.

6. Classification using human workers

In [18], we consider the use of error-control codes and decoding algorithms to perform reliable classification using unreliable and anonymous human crowd workers by adapting coding-theoretic techniques for the specific crowdsourcing application. We develop an ordering principle for the quality of crowds and describe how system performance changes with the quality of the crowd. We demonstrate the effectiveness of the proposed coding scheme using both simulated data and real datasets from Amazon Mechanical Turk, a crowdsourcing microtask platform. Results suggest that good codes may improve the performance of the crowdsourcing task over typical majority-vote approaches.

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REPORT OF INVENTIONS AND SUBCONTRACTS

(Pursuant to "Patent Rights" Contract Clause) (See Instructions on back)

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PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE ABOVE ORGANIZATION. RETURN COMPLETED FORM TO THE CONTRACTING OFFICER.

1.a. NAME OF CONTRACTOR/SUBCONTRACTOR Syracuse University	**c. CONTRACT NUMBER** W911NF-09-1-0244	**2.a. NAME OF GOVERNMENT PRIME CONTRACTOR** US Army	**c. CONTRACT NUMBER** W911NF-09-1-0244	**3. TYPE OF REPORT** *(X one)* a. INTERIM ☐ X b. FINAL
b. ADDRESS *(Include ZIP Code)* 113 Bowne Hall Syracuse, NY 13244-1200	**d. AWARD DATE** *(YYYYMMDD)* 20090506	**b. ADDRESS** *(Include ZIP Code)* 4300 S Miami Blvf. Durham, NC 27703	**d. AWARD DATE** *(YYYYMMDD)* 20090506	**4. REPORTING PERIOD** *(YYYYMMDD)* a. FROM 20090506 b. TO 20130815

SECTION I - SUBJECT INVENTIONS

5. "SUBJECT INVENTIONS" REQUIRED TO BE REPORTED BY CONTRACTOR/SUBCONTRACTOR *(If "None," so state)*

NAME(S) OF INVENTOR(S) *(Last, First, Middle Initial)* a.	TITLE OF INVENTION(S) b.	DISCLOSURE NUMBER, PATENT APPLICATION SERIAL NUMBER OR PATENT NUMBER c.	ELECTION TO FILE PATENT APPLICATIONS (X) d. (1) UNITED STATES (a) YES	(1) UNITED STATES (b) NO	(2) FOREIGN (a) YES	(2) FOREIGN (b) NO	CONFIRMATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER (X) e. (a) YES	e. (b) NO
N/A								

f. EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR/SUBCONTRACTOR

(1) (a) NAME OF INVENTOR *(Last, First, Middle Initial)*	(2) (a) NAME OF INVENTOR *(Last, First, Middle Initial)*
(b) NAME OF EMPLOYER	(b) NAME OF EMPLOYER
(c) ADDRESS OF EMPLOYER *(Include ZIP Code)*	(c) ADDRESS OF EMPLOYER *(Include ZIP Code)*

g. ELECTED FOREIGN COUNTRIES IN WHICH A PATENT APPLICATION WILL BE FILED

(1) TITLE OF INVENTION	(2) FOREIGN COUNTRIES OF PATENT APPLICATION

SECTION II - SUBCONTRACTS *(Containing a "Patent Rights" clause)*

6. SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR *(If "None," so state)*

NAME OF SUBCONTRACTOR(S) a.	ADDRESS *(Include ZIP Code)* b.	SUBCONTRACT NUMBER(S) c.	FAR "PATENT RIGHTS" d. (1) CLAUSE NUMBER	d. (2) DATE (YYYYMM)	DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S) e.	SUBCONTRACT DATES (YYYYMMDD) f. (1) AWARD	f. (2) ESTIMATED COMPLETION

SECTION III - CERTIFICATION

7. CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR *(Not required if: (X as appropriate))* ☐ SMALL BUSINESS or X NONPROFIT ORGANIZATION

I certify that the reporting party has procedures for prompt identification and timely disclosure of "Subject Inventions," that such procedures have been followed and that all "Subject Inventions" have been reported.

a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL *(Last, First, Middle Initial)* Gilbert, Mary Ellen	**b. TITLE** Research Administrator	**c. SIGNATURE** MEGilbert	**d. DATE SIGNED** 10152013